RP 815 Wind Turbine Grease Analysis Test Methods

The following recommended practice (RP) is subject to the disclaimer at the front of this manual. It is important that users read the disclaimer before considering adoption of any portion of this recommended practice.

This recommended practice was prepared by a committee of the AWEA Operations and Maintenance (O&M) Committee.

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Purpose and Scope

The scope of “Wind Turbine Grease Analysis Test Methods” will focus on specific test methods which should be applied for accurate grease testing and analysis.

Introduction

Accurate grease analysis results are critical to the successful diagnosis of wear rates, contamination levels, oxidation levels, and consistency of the grease. Inaccuracies can be due to improper test methods selected for the particular application, inadequate quality control of test methods, or poor sampling techniques. This practice is intended to assist in proper test selection specific to wind turbine grease samples, thus allowing for proper diagnosis and reasonable corrective action based on sound limits and warnings.

Test methods specific to wind turbine main bearing grease should provide accurate oil test results on which to base good maintenance decisions and reduce operating costs. Effectiveness of grease analysis test methods is directly and completely dependent on the accuracy of the samples obtained for this purpose. Consult AWEA guidance on grease sampling methods, developed in compliance with ASTM D7718, “*Standard Practice for Obtaining In-Service Samples of Lubricating Grease*”.

Wind Turbine Grease Analysis Test Methods

1. Procedures

Prior to sending grease samples to your laboratory, it is important to establish with your laboratory which tests are to be performed on the used in-service grease, the grease volume needed to run these tests, and the condemning limits that should be applied. Some methods exist that enable an in-service grease analysis basic test slate including measurement of wear, consistency, contamination, and oxidation with as little as 1 gram of grease. Some tests require greater quantities of grease. In all cases, the grease submitted for sampling must be representative of the condition of the grease actively lubricating the bearing and receiving wear particles by nature of proximity to the wearing surfaces.

2. Grease Analysis Methods

OEMs may require grease analysis more often during initial startup on new turbines. Grease analysis can be performed every 6 months or annually, depending on component age, history, or other factors. Typically, samples can be taken while up tower performing other routine maintenance tasks. A typical test slate for grease analysis may include the following tests (methods listed in this section are recommended for use with wind turbine grease):

- Ferrous debris quantification*
- Consistency testing, such as cone penetration, rheometry, or die extrusion test*
- Infrared spectroscopy (FTIR)
- Anti-oxidant additive quantification, such as linear sweep voltammetry (ASTM D7527) or short-path FTIR
- Elemental spectroscopy, such as RDE or ICP
- Visible appearance (manually or grease colorimetry*)
- Water PPM (D6304, oven method)

NOTE: Those tests marked with asterisk (*) are a pending ASTM work practice in review for ASTM standard in CS96 committee as of the writing of this procedure.

2.1. Ferrous Debris Quantification

This test determines the amount of ferromagnetic material present in the sample. Because the metallurgy of wind turbine drivetrain components are primarily ferrous, this test is effective at monitoring ferrous wear debris generation rate. Several methods exist that measure the change in voltage as it is dropped through an electromagnetic field. The Hall effect refers to the voltage induced in a conductor in the presence of magnetic flux. One method must be selected and applied consistently, as there are differences in values produced by different ferrous debris monitoring technologies.

The values derived from such analyses are used as a general flagging mechanism for the lab to detect high wear levels. An action level should be developed based on the method used and statistical analysis or evaluation of historical values against observed conditions. When the sample has exceeded the action level, analytical ferrography is recommended to characterize the nature and severity of the wear. It should be noted that wear debris in grease is cumulative until flushed out by introduction of new grease and that replenishment rate must be factored into the development of action criteria.

2.2. Consistency Test

The consistency of grease is a function of the base oil and thickener and their types and ratios. The consistency is important in ensuring that the grease will stay in place in the intended lubrication point and affects the ability of the grease matrix to supply liquid oil to maintain a lubricant film to separate surfaces in relative motion. After some time in service, the consistency can change due to variables such as grease mixing, aging, overheating, excessive working, or contamination. In new grease, consistency is measured by cone penetration and an NLGI number is assigned to the grease on a scale from 000 to 6. In-service greases usually cannot be tested per the cone penetration method due to the large quantities required, so the rheometer or die extrusion methods are typically used.

In die extrusion, the consistency is determined by measuring the load required to force the grease through an orifice of know dimensions at varying speeds. The consistency of the grease is compared to the new baseline grease. Drastic increases or decreases in the consistency correspond to severe thickening or thinning of the grease, which could indicate abnormal operating conditions and/or compromise reliability.

2.2. Consistency Test
(continued)

For rheometry, the grease is placed between opposing plates that are rotated and oscillated while measuring the resulting force, which is a function of the consistency and flow characteristics of the grease. Parameters measured include storage modulus (grease flow), oscillation stress (oil content and shear from thickener), and recoverable compliance (tendency to tunnel or channel in the bearing or gearbox).

In either test, results are compared to new, fresh grease, and criteria is developed to flag samples that deviate significantly in service from the new grease. Due to the geometry and loads in wind turbine main bearings, consistency reductions of as much as 40-50% may be considered typical for in-service greases and it is necessary to establish action criteria based on statistical analysis or comparative operating histories.

2.3. FTIR Infrared Spectroscopy

Infrared (IR) spectroscopy or Fourier transform infrared spectroscopy (FTIR) have been used for many years to provide rapid, low cost, offline analyses of oil samples. The technology passes an infrared light source through a lubricant sample to an infrared detector. The light that passes through the oil is influenced by the fluid properties as oil contaminants and additives absorb infrared radiation at varying frequencies. By comparing the frequency spectrum of new and used oil samples it is possible to determine the lubricant properties, such as water, soot, oxidation, nitration, and glycol levels.

Through advances in electronics manufacturing techniques, IR technology is beginning to make its way into online sensing devices. Current technology does not have the refined measurement capabilities of laboratory devices. However, they do offer multi-parameter trending capabilities which can provide valuable, real-time insight into fluid condition.

FTIR is used to fingerprint the molecular bonds in the grease. An IR beam is passed through a thin grease film, of known dimension, and the resulting absorbance spectrum is used to characterize the organic components of the grease. Alternatively, other sample introduction methods can be used, such as attenuated total reflectance (ATR) or photoacoustic spectroscopy. By comparing the in-service sample to the baseline, oxidation, grease mixing, and organic contamination, including water, can be detected.

2.4. Linear Sweep Voltammetry

Linear sweep voltammetry, know commercially as "RULER", measures the remaining useful life of the anti-oxidant additive package. A voltage sweep is applied to the sample as the current is measured. The graph of current and time will contain peaks which correspond to different anti-oxidants, and the concentration remaining in the sample is proportional to the area under the curve for these peaks. The results are reported as a percentage of the concentration found in the baseline grease.

2.5. Atomic Emission Spectroscopy

The quantification of metallic elements in grease can be accomplished by rotating disc electrode (RDE), inductively coupled plasma (ICP), or x-ray fluorescence (XRF). While atomic emission spectroscopy is routine for oil analysis, sample preparation is unique for greases. The grease must either be dissolved by a clean, filtered solvent and analyzed, or use a uniform preparation method to introduce the solid grease to the analyzer. For ICP, the sample must be fully dissolved. The selection of the solvent system for each grease type is important to the effectiveness of the method. ASTM D7303 governs the ICP method. For the XRF and RDE methods, direct application, without dissolving sample, preparation methods are used in industry and standards are under development.

For the solvent methods, the grease is dissolved in reagent grade organic solvent and vaporized in the sample chamber. The atoms are excited with an electric arc and the light patterns emitted are compared with the known patterns of 19 different metals. The spectrometer detects most wear particles such as iron and Babbitt, as well as certain additive elements that could indicate grease mixing. All results are recorded in parts per million (ppm). The limitation of this technology is the instrument is not sensitive to particles larger than about 6 microns because they do not vaporize in the AC arc.

2.6. Grease Colorimetry

Grease colorimetry measures light absorbance in the visible light range (400 nm to 700 nm) under controlled repeatable conditions. The resulting spectrum has peaks which differentiate colors at a much higher sensitivity than the human eye. Because some grease products contain unique dyes, this method can be used to detect grease mixing when the true baseline is known.

2.6. Grease Colorimetry
(continued)

This method can validate observed appearance changes in greases, trend darkening due to aging or overheating, characterize dye formulations of new grease, and approximate the concentration of certain particulate contaminants, such as coal dust, soot, or other solids accumulating in the grease. As an alternative method, subjective visual analysis of the grease and comparison to the appearance of new or typical used greases can be made.

2.7. Water PPM

The presence of moisture in lubricating greases leads to corrosion, wear, and an increase in debris load which contributes to bearing and gear fatigue. While FTIR can identify gross levels of water in greases, it is typically not accurate in assessing quantitative values.

A quantitative test is the Karl Fischer titration by oven method, ASTM D6304. This test method detects the presence of water by thermal mass transfer of the grease to a dry gas, which is then titrated to determine parts per million of water in the grease. Action criteria can be determined from statistical analysis of a given population of similar wind turbine drivetrain components in a certain environmental application or comparative operating histories.

3. Interpreting Grease Analysis Results

3.1. Consult your specific laboratory for help with interpreting results and understanding the lab reports.

3.2. Appropriate alarms (min./max., percent change, deviation) will vary based on machine and population of sample data.

3.3. Any opportunity to evaluate and inspect a removed wind turbine drivetrain component should be made to correlate as-found conditions to the preceding grease analysis trends and expand the knowledge base for developing more precise and accurate action criteria.

Summary

A comprehensive, disciplined approach to grease sample collection, specific analysis methods, trend monitoring, and proper condemning limits can help identify grease, bearing, and gear issues. This enables wind farm operators to make cost-effective servicing and maintenance decisions and predict bearing and gear failures so that pre-emptive action can be taken. Overall, the objective supported by this recommended practice is to accumulate solid data in order to reduce guesswork, improve uptime and availability, and ultimately to reduce O&M costs.